

Aerosol Microphysics and Optical Properties - INTEx

INTEx Workshop – March 29 – April 1, 2005



Alaska fire plume

University of Hawaii

Hawaii Group for Environmental Aerosol Research

A. Clarke, S. Howell, C. McNaughton, Y. Shinozuka, J. Zhou, V. Kapustin

Dry Size Distributions, Volatility, Aerosol scatter./absorp., $f(RH)$

and in conjunction with

Langley Aerosol Research Group Experiments

B. Anderson, L. Thornhill, E. Winstead, C. Hudgins, A. Omar

Measurements

- Size distributions - **DMA****(0.01-.15um); **OPC**** (0.15-1.5um); APS>1um
- Condensation Nuclei (total, refractory, volatile at 300C) ($D_p > 0.10\mu\text{m}$)
- **Ultrafine** Condensation Nuclei (total) ($D_p > 0.003\mu\text{m}$)
- Light scattering & backscattering (Total and Submicron at 450, 550, 700nm)
- Light absorption (est. Black Carbon at 450, 550, 700nm)
- $f(\text{RH})$ or Gamma (humidity dependence of light scattering)

**** OPC (processing correction)**

DMA (size correction at small sizes)

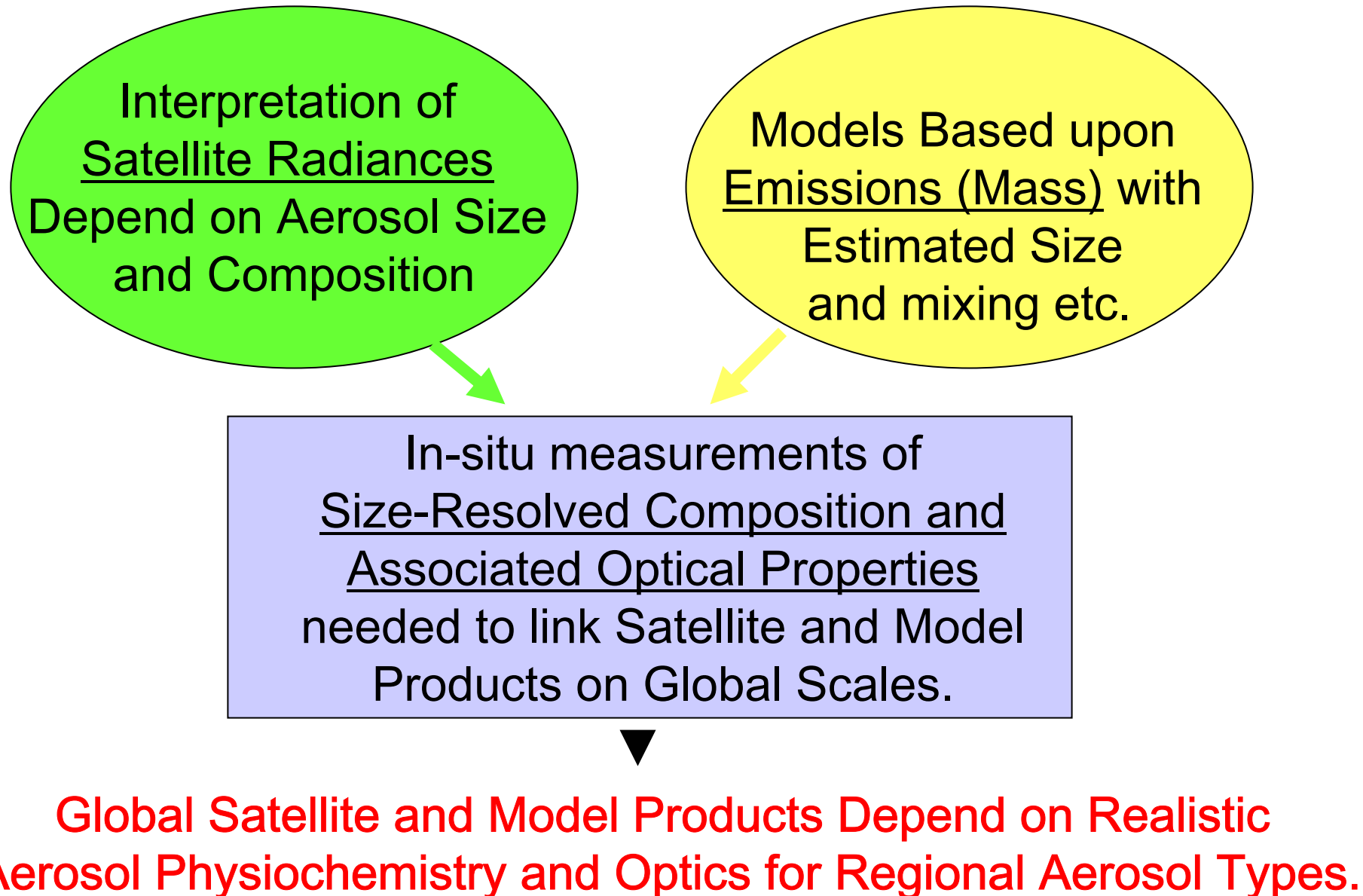
Ultrafine (about 9% flow correction)

These will have revisions complete by next week ready for next merge
– replace with corrected data when merge available.

Some Interests and Objectives

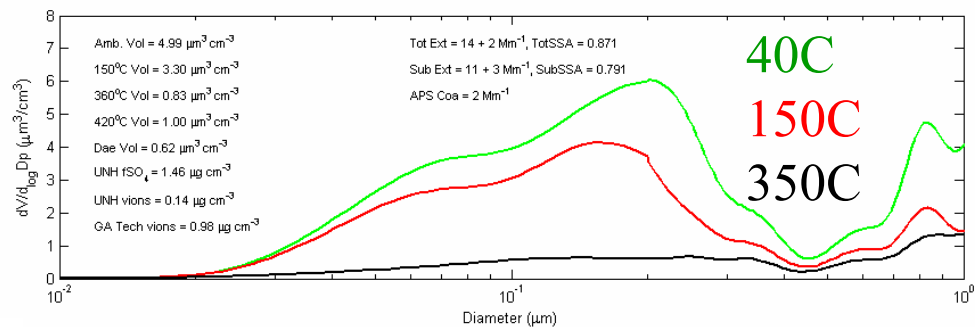
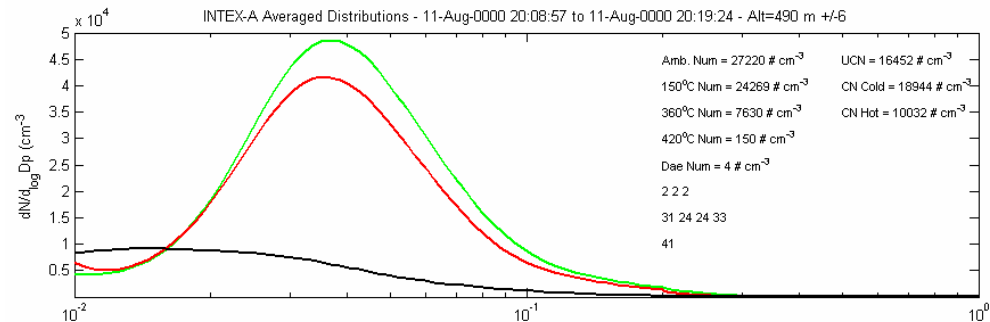
- Size Distributions and Volatility as a measure of size-resolved composition and black carbon estimates
- Relation to aerosol humidity dependent growth and optics
- Spectral dependence of optical properties linked to sources
- Coupling of measured and model aerosol properties
- Atmospheric radiation and satellite products (MISR – MODIS)
- In-situ assessment of satellite estimates of CCN

In-situ Aerosol Physiochemical Data Needed to Link Optically Derived Satellite Products to Emission (mass) Based Global Models



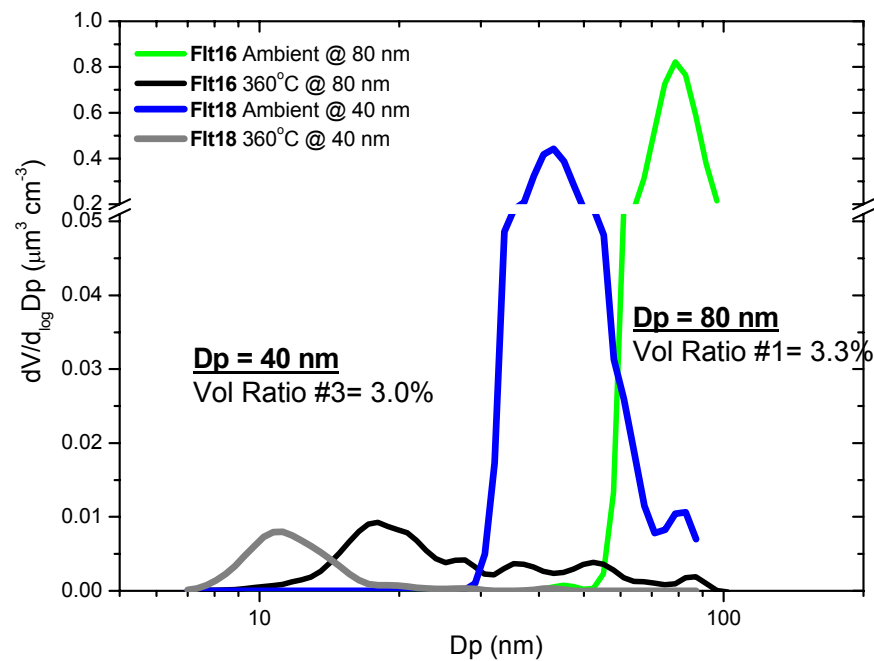
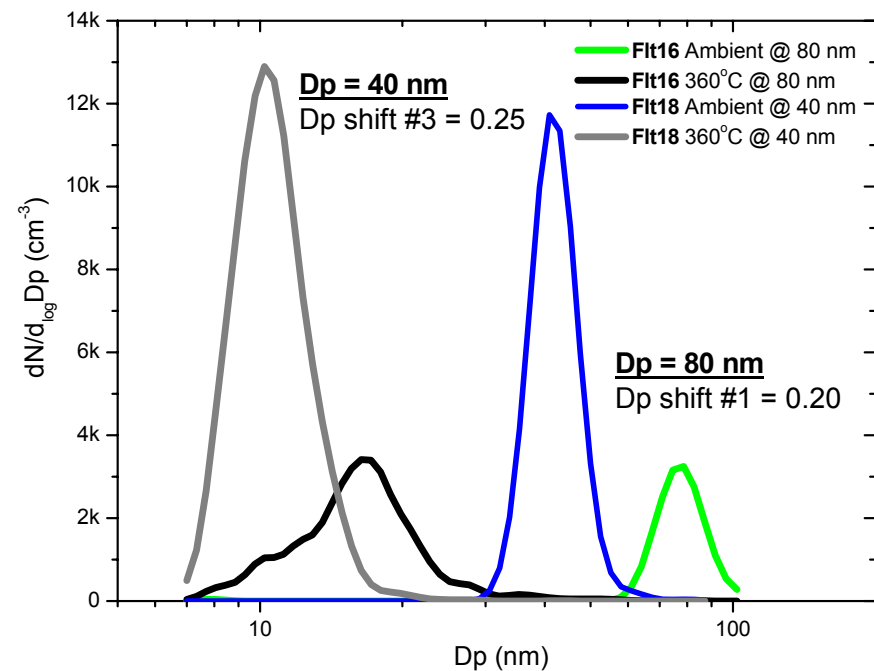
Thermally Resolved Composition

Flight 18 – Fresh Pollution On Approach to Mid-America, IL



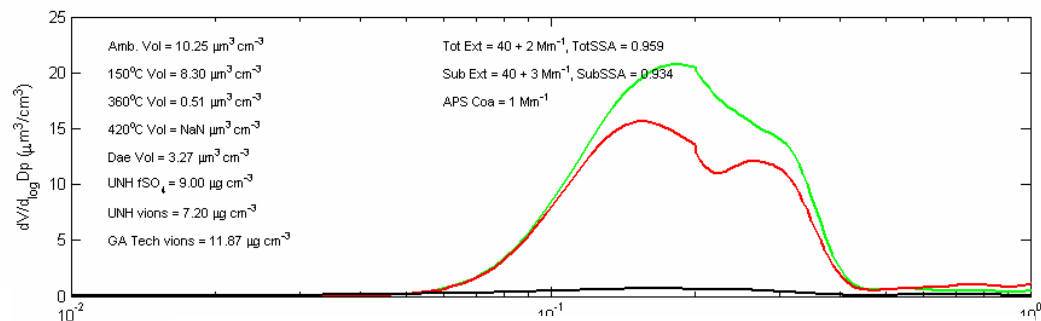
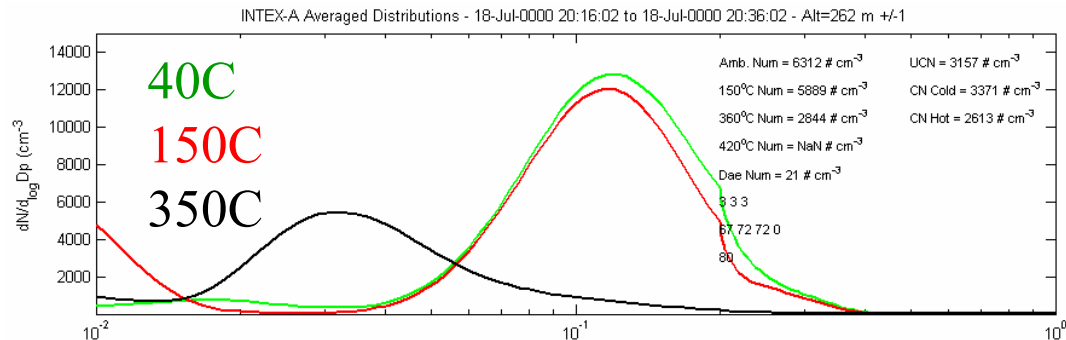
Fresh Pollution

Fresh Pollution

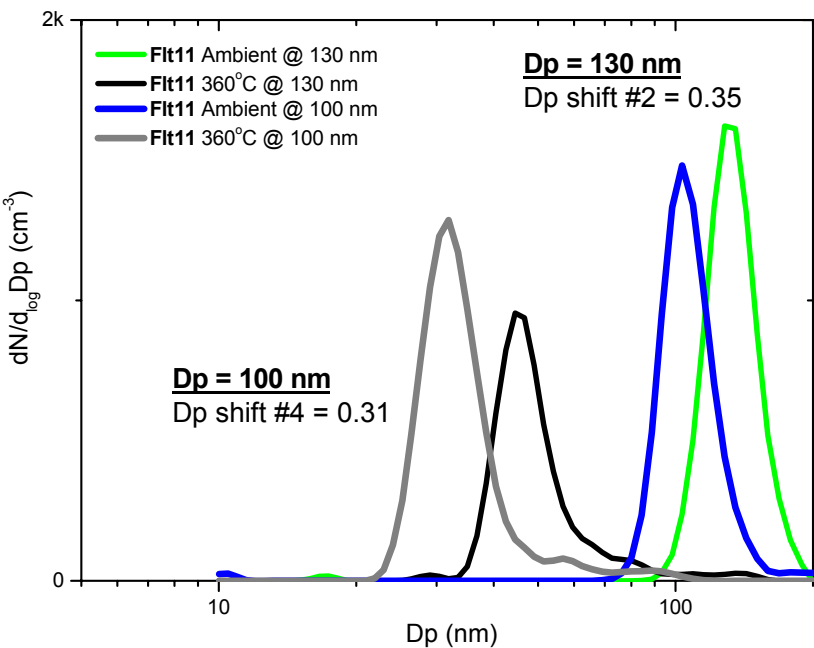


Thermally Resolved Composition

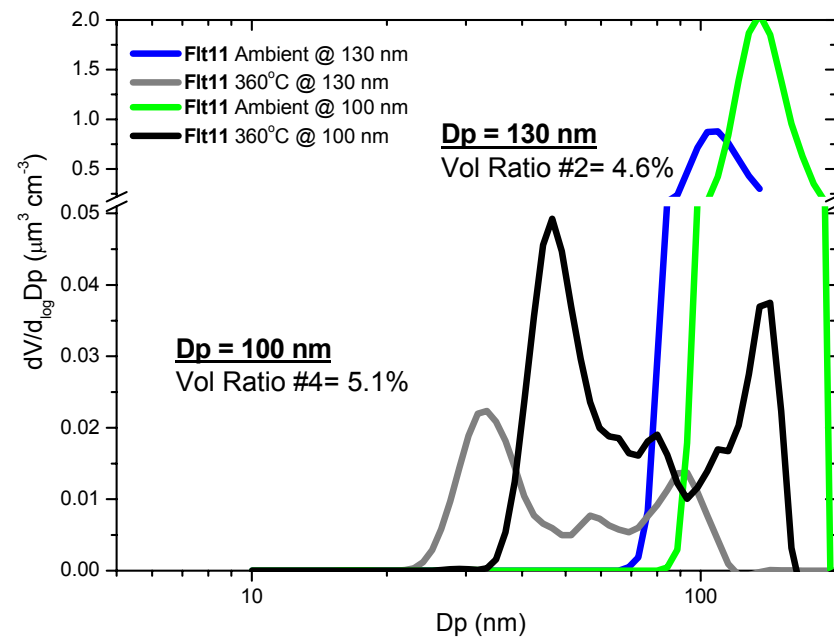
Flight 09 – Aged Pollution Southern Coast of Newfoundland, Canada



Aged Pollution - Gulf of St. Lawrence, Canada

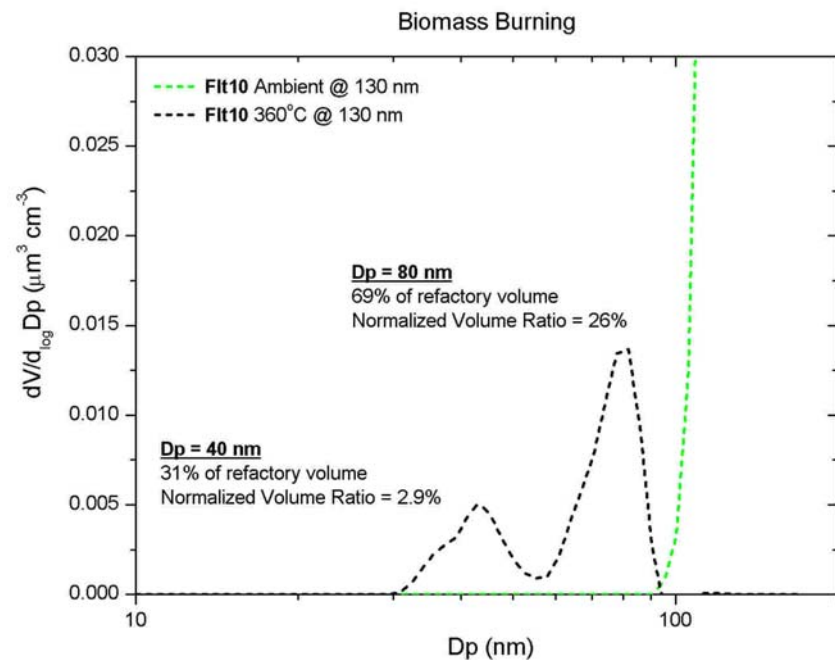
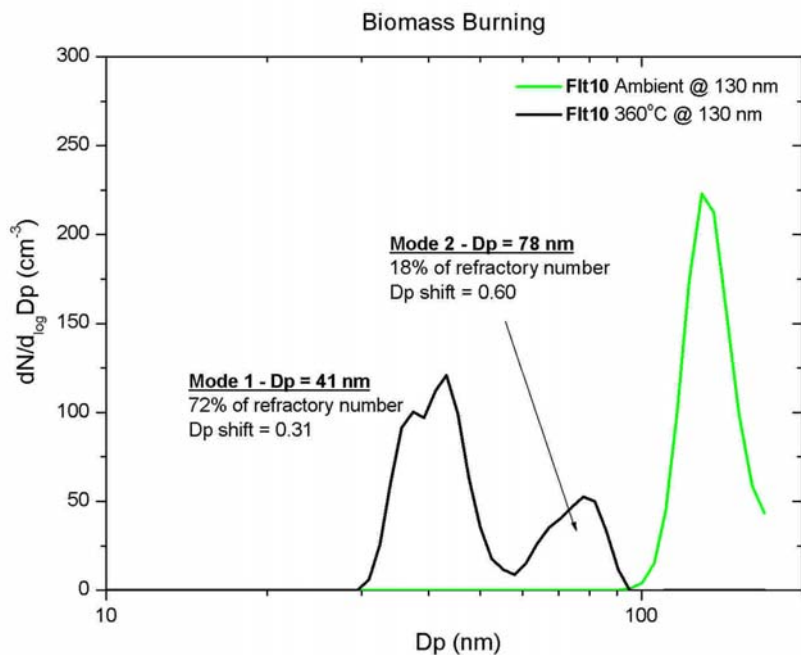
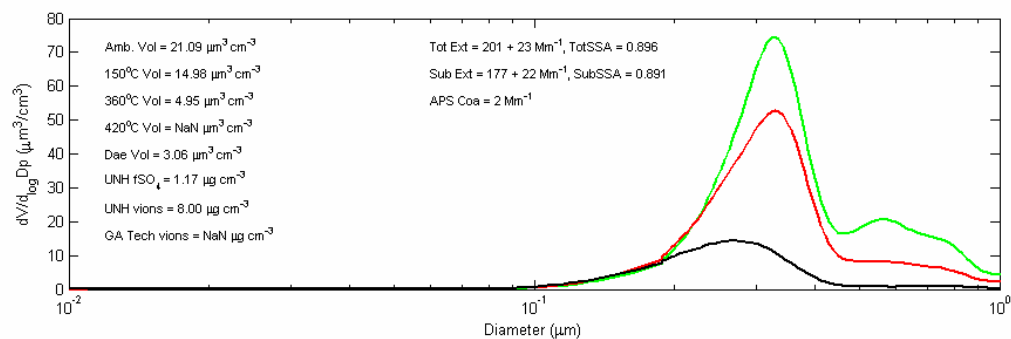
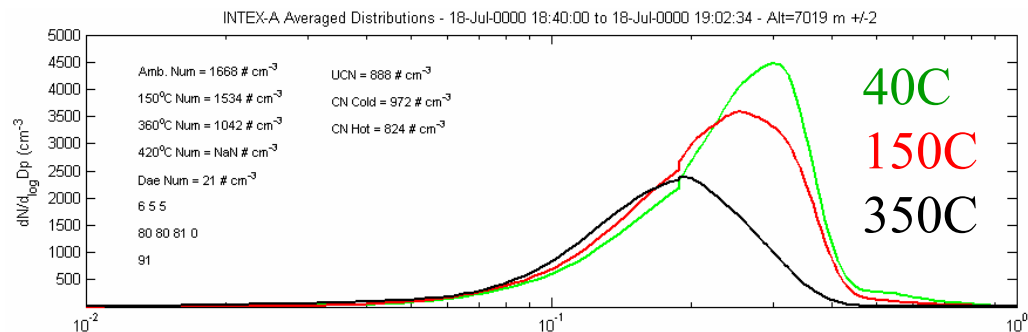


Aged Pollution - Gulf of St. Lawrence, Canada



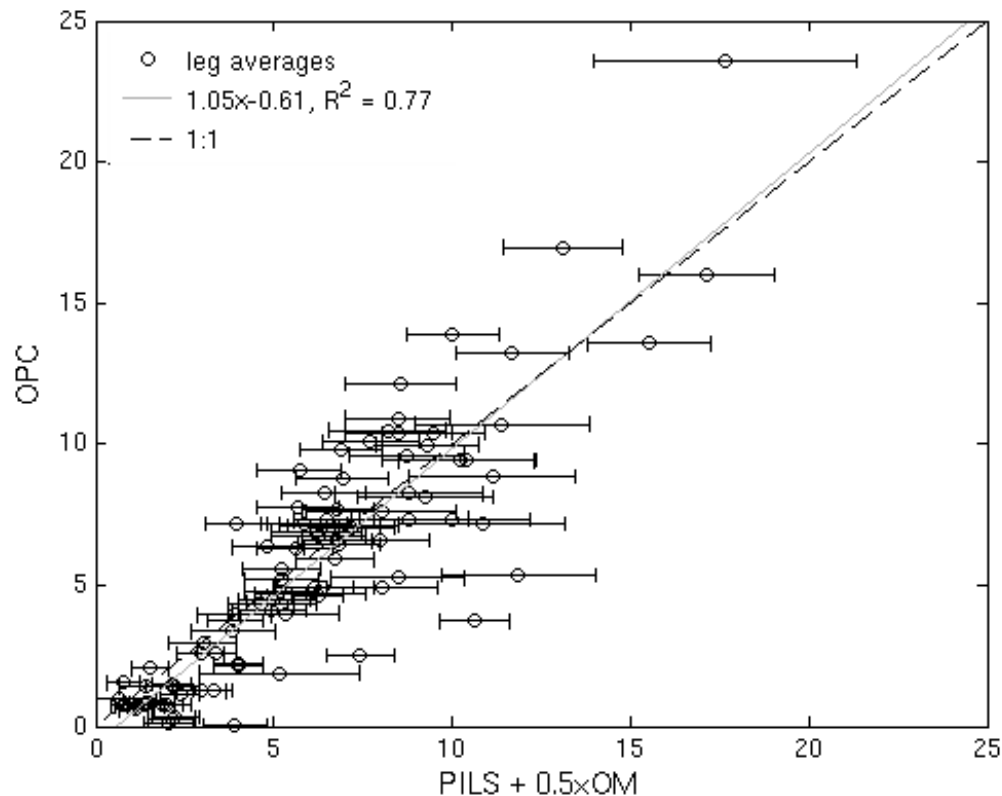
Thermally Resolved Composition

Biomass Burning Aloft over Huntsville at 3600m



Link between aerosol volatile volume and sum of PILS soluble species and 1/2 Organic Matter (OM) (soluble est.)

ACE-Asia: OM about 2 x SO₄ mass



INTEX?
OM ?>SO₄
OC vs. WSOC?

Significant Observations

Aerosol Optical properties are strongly influenced by
water uptake by soluble species

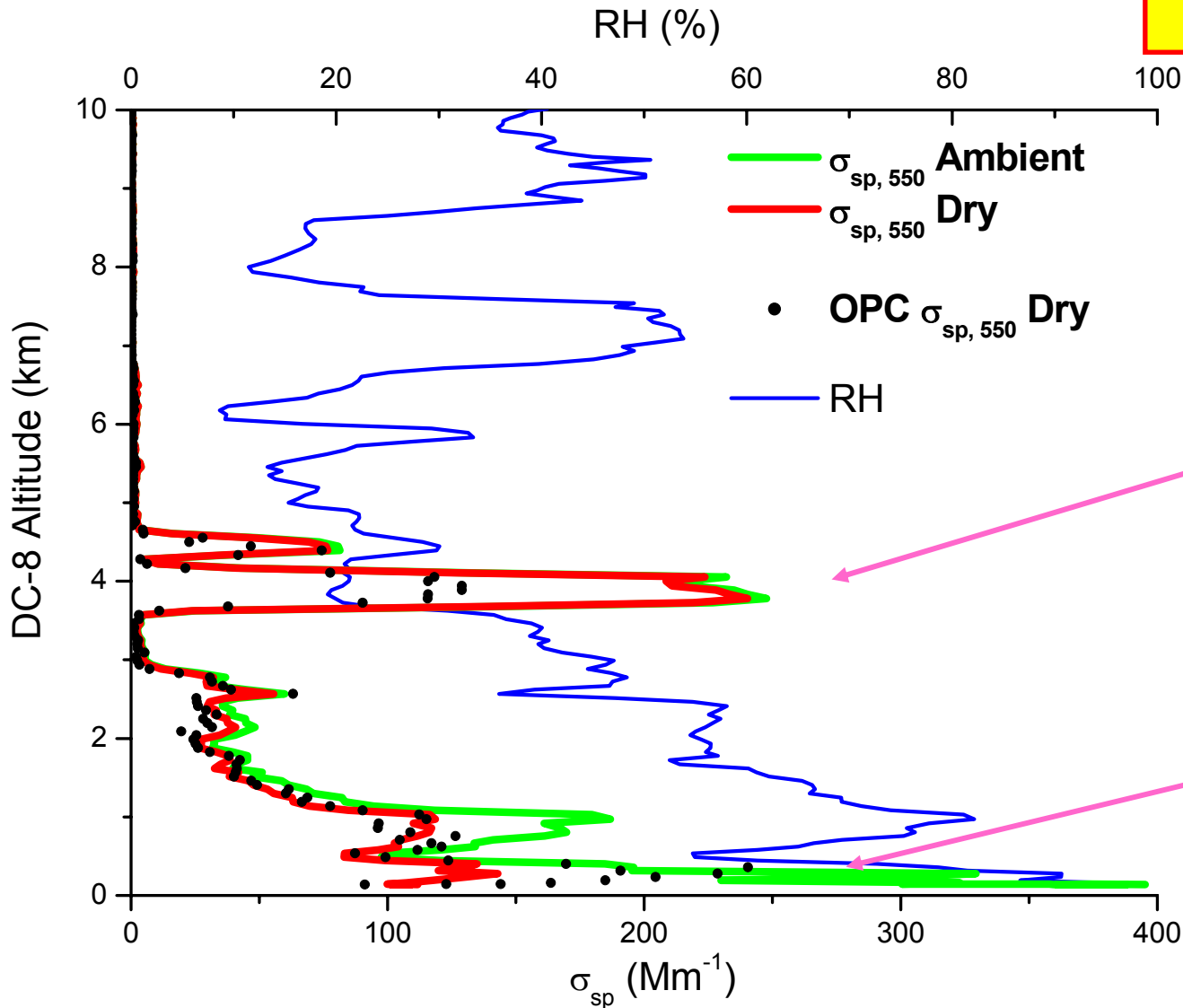
But

A significant fraction of INTEx aerosol can be
Organic Matter (ICARRT data) and largely
insoluble

This changes our prior estimates of the response of
regional light scattering to humidity described by
 $f(\text{RH})$ or γ

Ambient light scattering is calculated from **dry scattering** using γ . Gamma is empirically derived from our *in-situ* measurements of $f(RH)$ and **ambient humidity**.

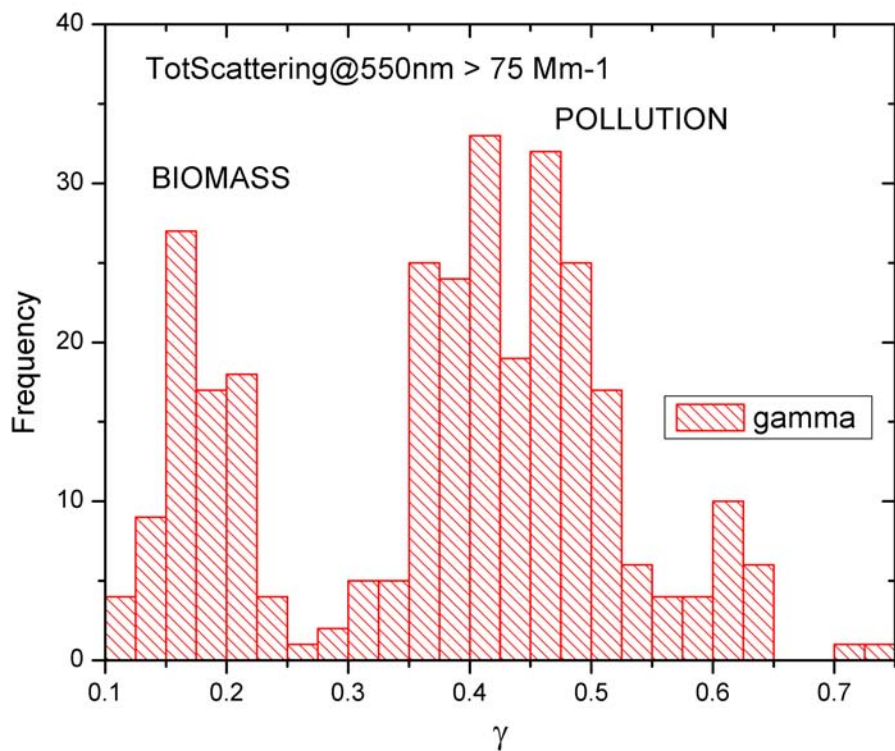
$$\sigma_{sp,amb} = \sigma_{sp,dry} \cdot \left[\frac{\left(1 - \frac{RH_{dry}}{100}\right)}{\left(1 - \frac{RH_{wet}}{100}\right)} \right]^{\gamma}$$



Forest Fires
Low ambient RH
 $\sigma_{sp, dry} \approx \sigma_{sp, amb}$

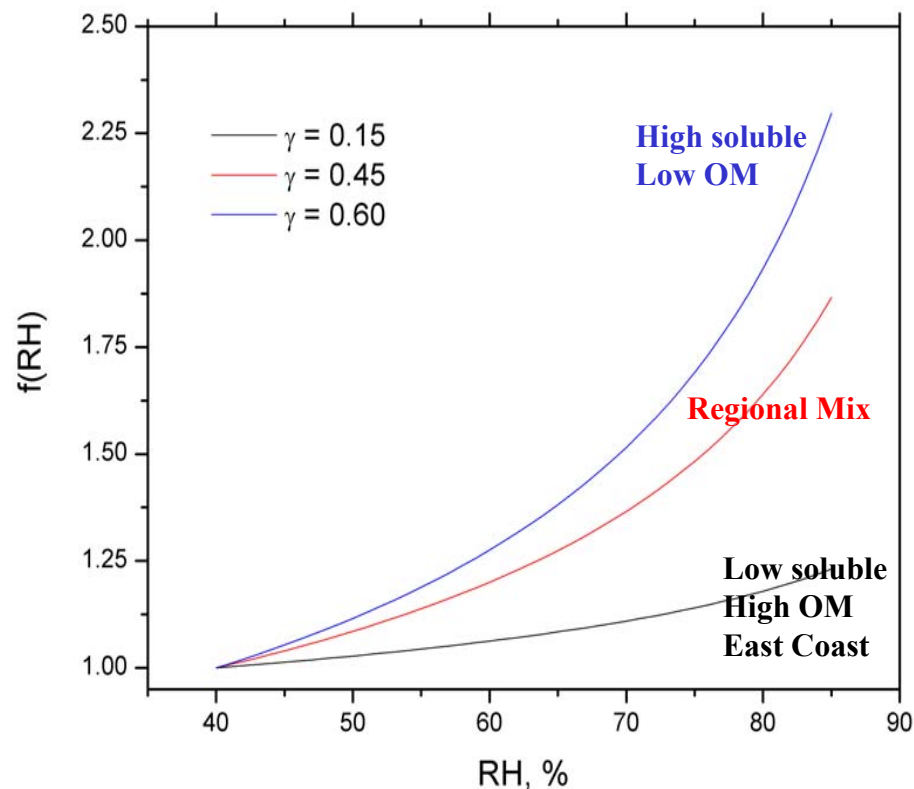
Pollution
High ambient RH
 $\sigma_{sp, dry} \neq \sigma_{sp, amb}$

Frequency of γ for three common aerosol types evident during INTEX



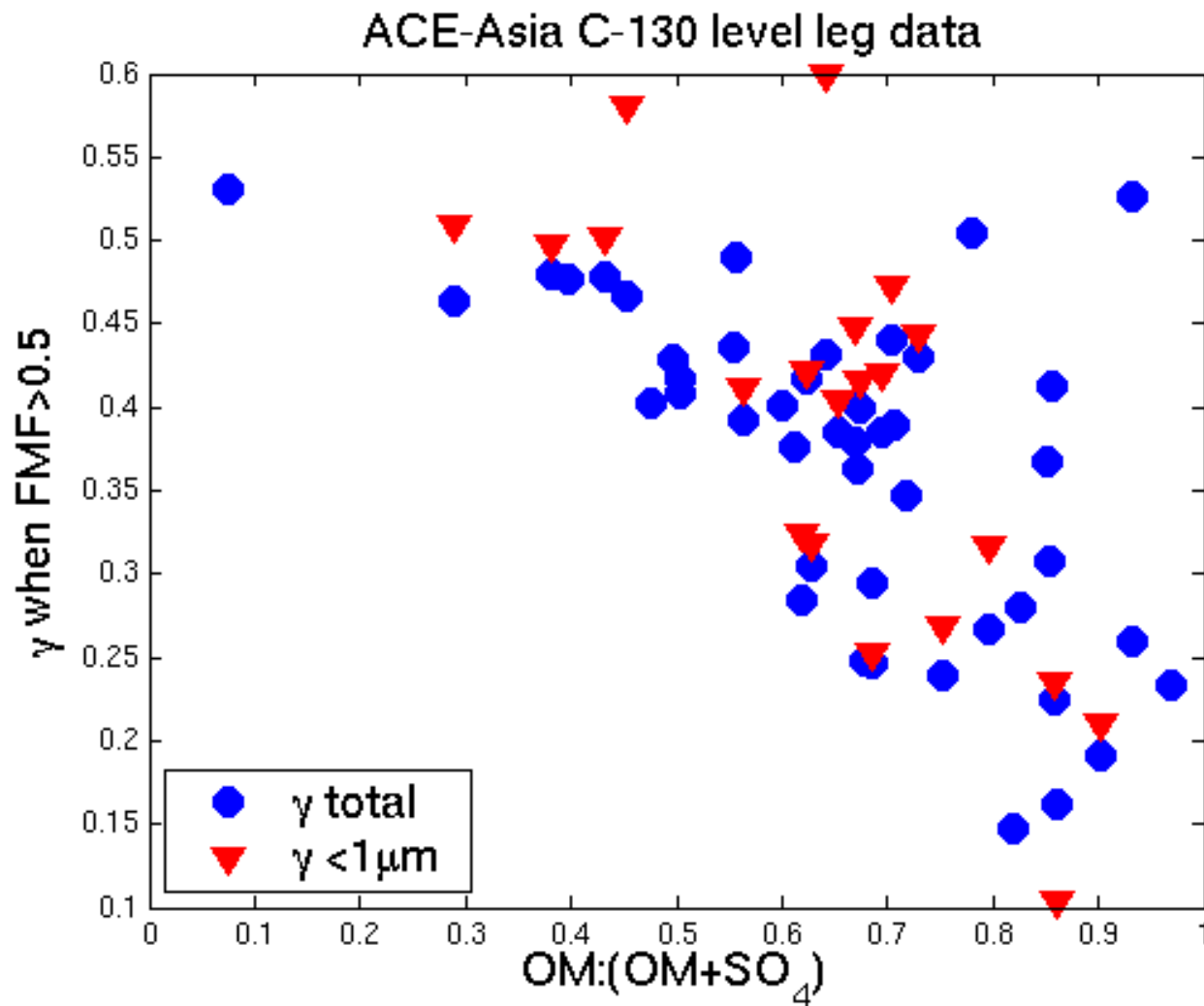
$$\sigma_{sp,amb} = \sigma_{sp,dry} \cdot \left[\frac{\left(1 - \frac{RH_{dry}}{100}\right)}{\left(1 - \frac{RH_{wet}}{100}\right)} \right]^\gamma$$

f(RH) dependence on gamma



The decrease in $f(RH)$ or γ due to the presence of increasing fine mode organic aerosol fraction – ACE-Asia

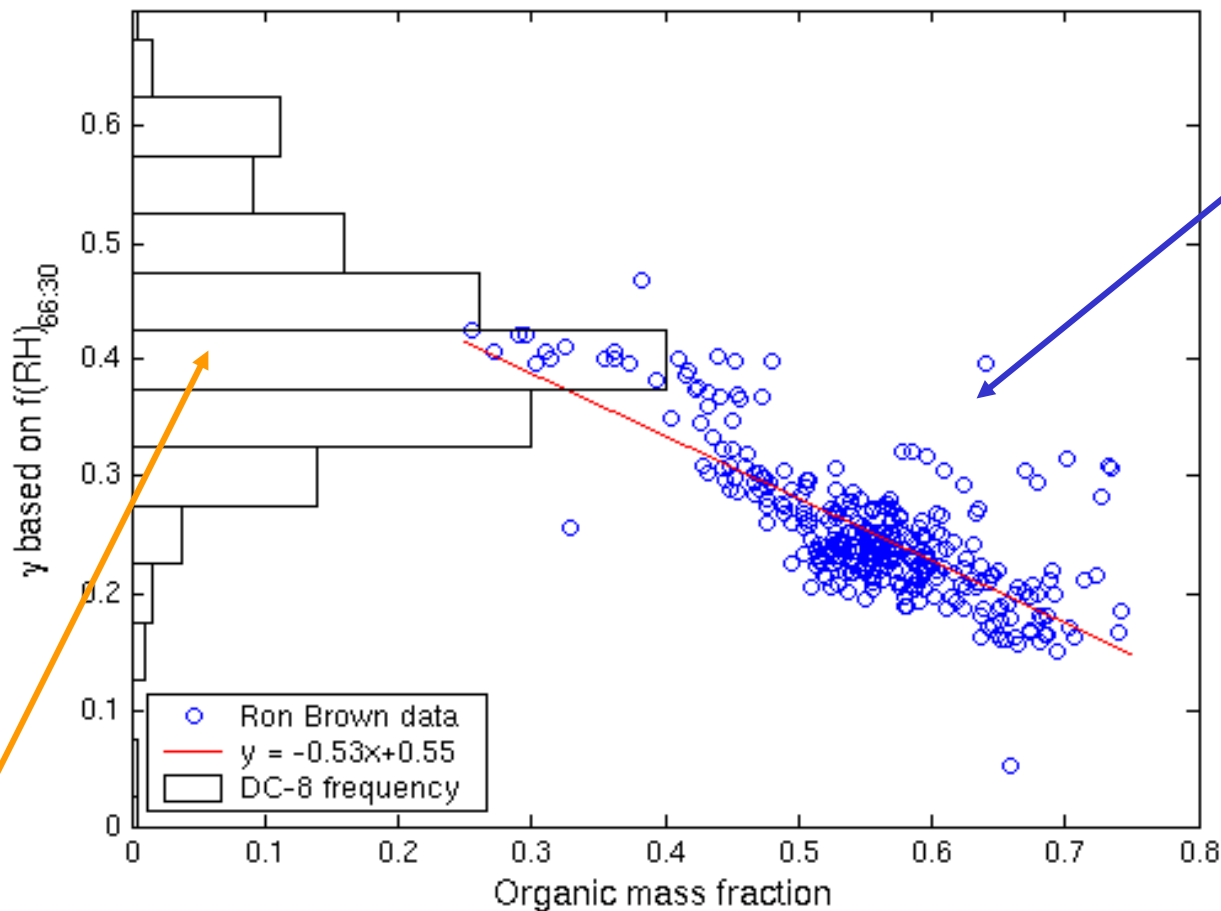
S. Howell, A. Clarke, B. Huebert, R. Weber –for CCSP Assessment 2005



Increasing Organic Mass Fraction >>>>>

The decrease in $f(RH)$ or γ due to the presence of increasing fine mode organic aerosol fraction – ICARRT/INTEX

P. Quinn, T. Bates, T. Baynard, S. Howell, A. Clarke –for CCSP Assessment 2005



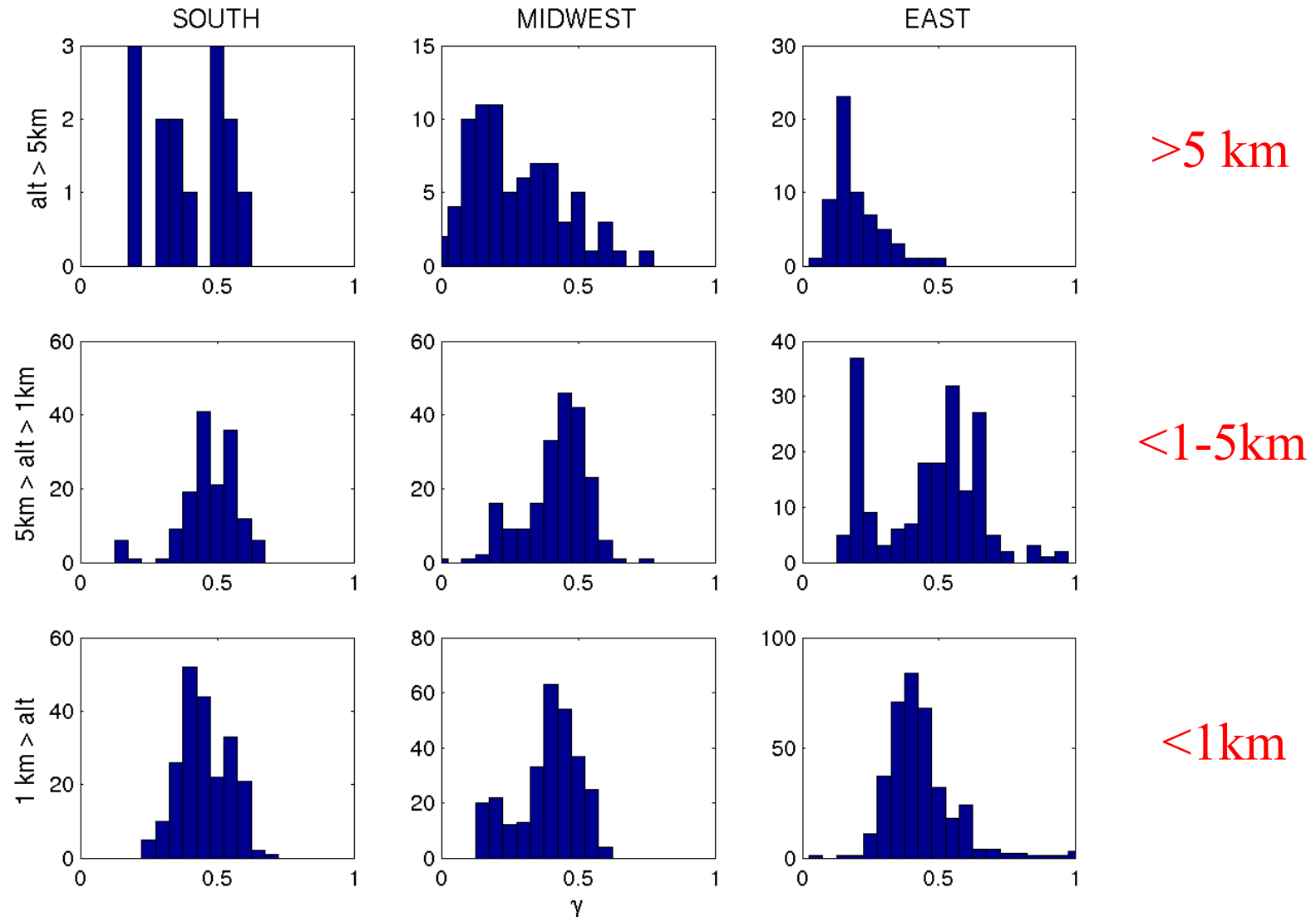
Ron Brown data for low level outflow off continent over Gulf of Main, ICARRT.

Increasing Organic Mass Fraction >>>>>

Histogram for all DC-8 data below 2km and east of 75W, INTEX

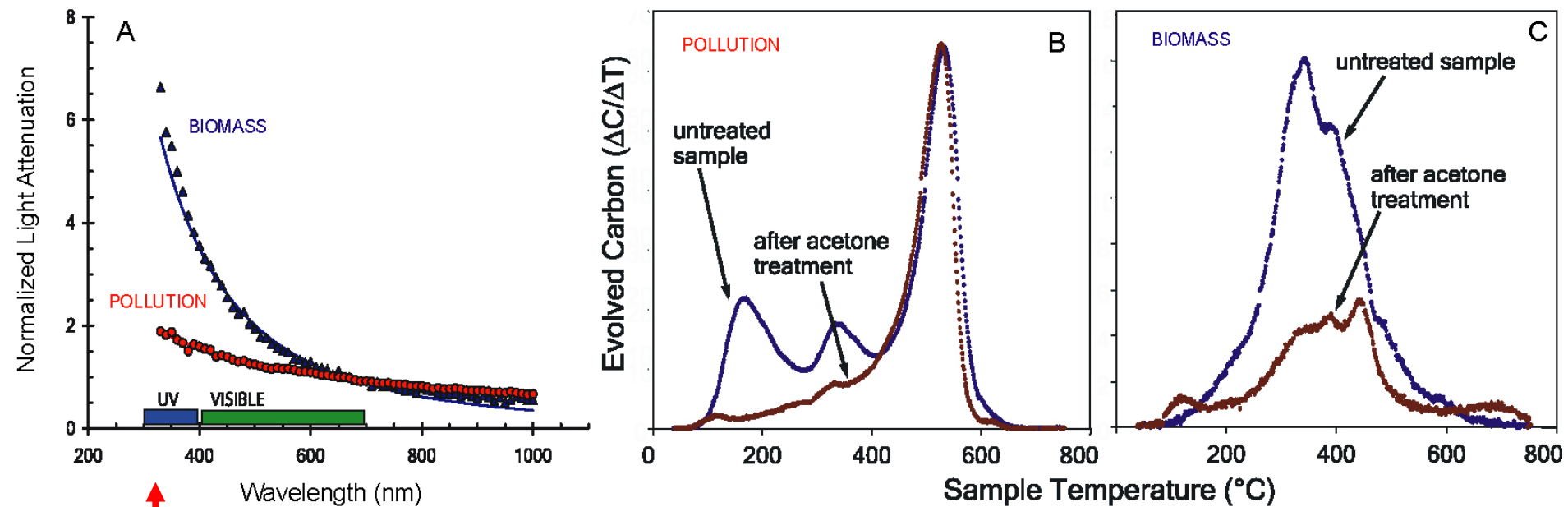
Some Altitude and Regional variations in Gamma (f(RH))
Tendency for Mid-level increases in f(RH) relative to surface except for biomass influence but generally lower values aloft → different chemistry

INTEX DC-8 data



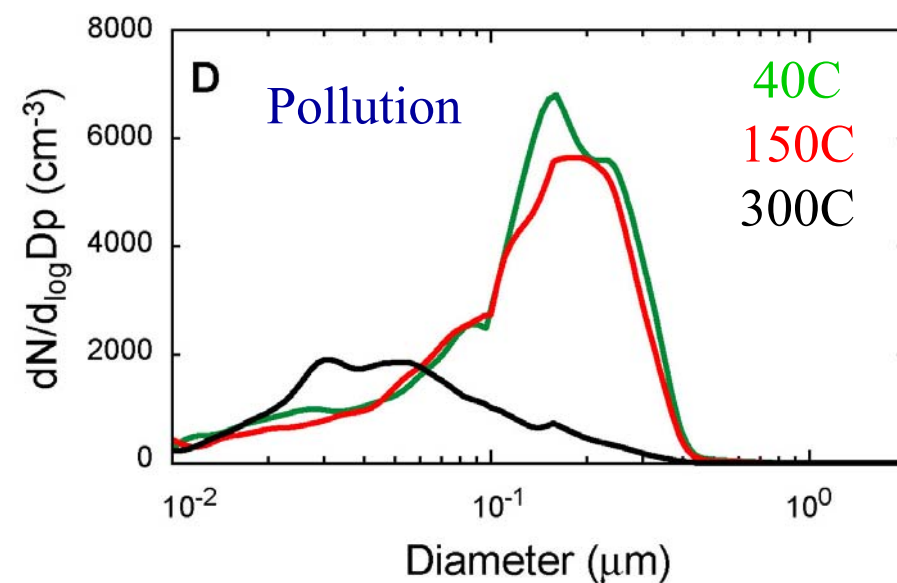
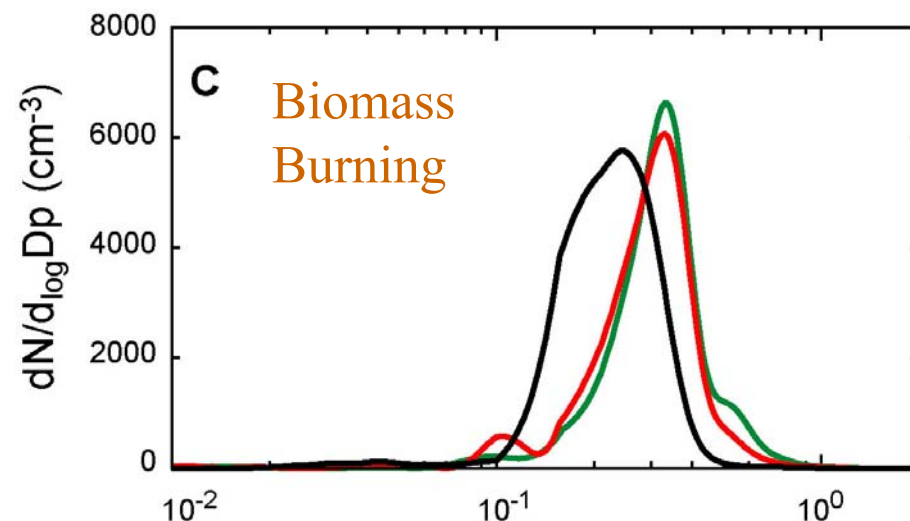
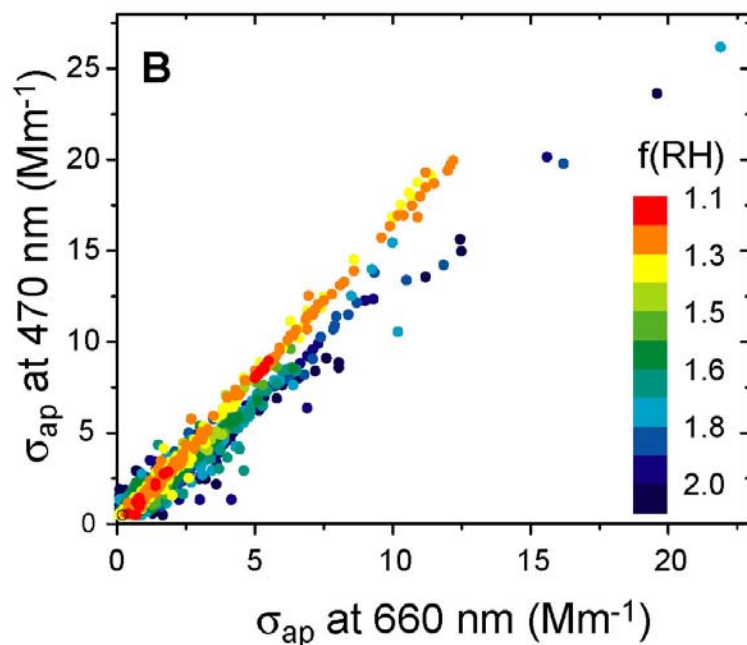
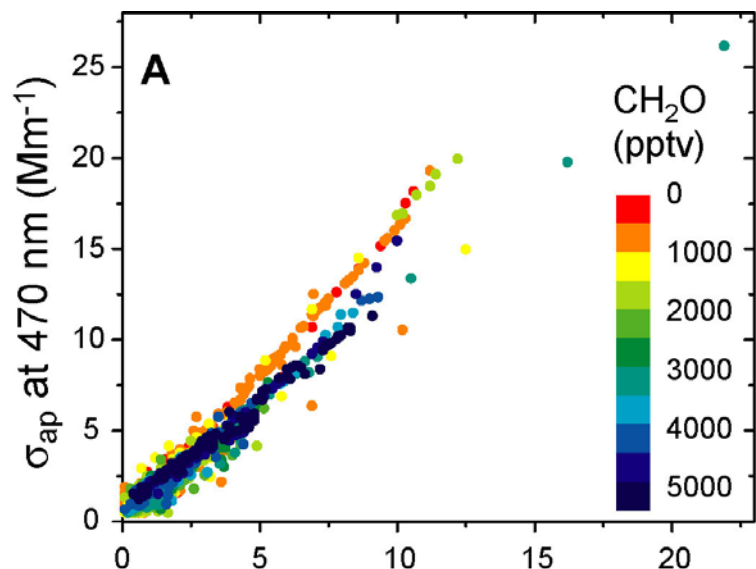
Spectral dependence of absorption recently related in part to Organic Matter and its differences in Pollution and Biomass Aerosols As evidenced in their thermal evolution before and after acetone treatment.

Kirchstetter et al., JGR, D21208,2004 :Spectral light absorption by aerosols

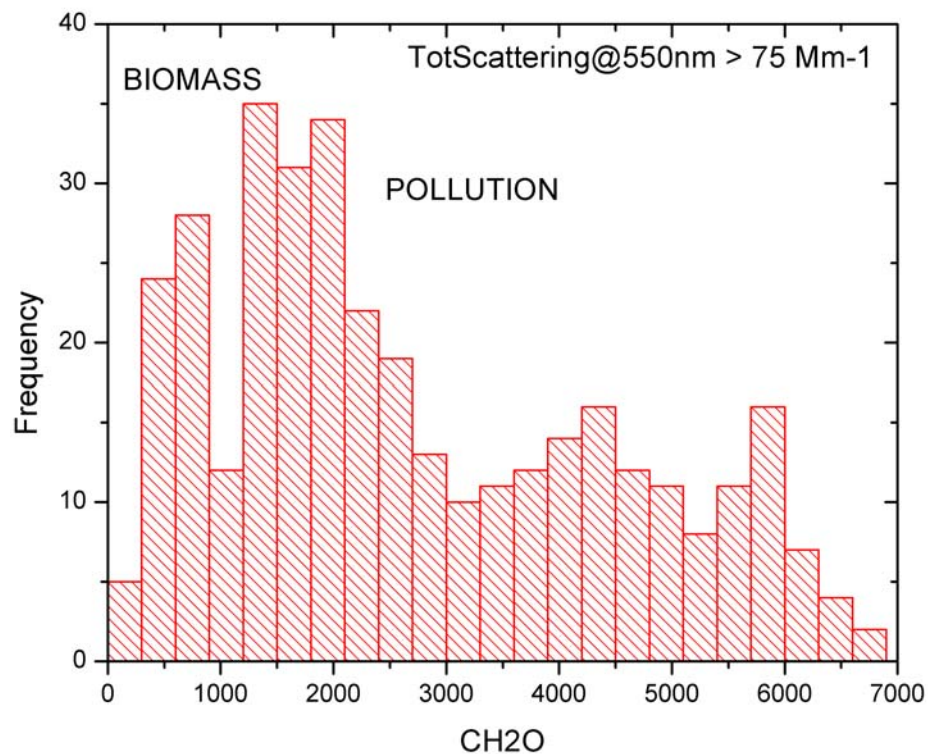
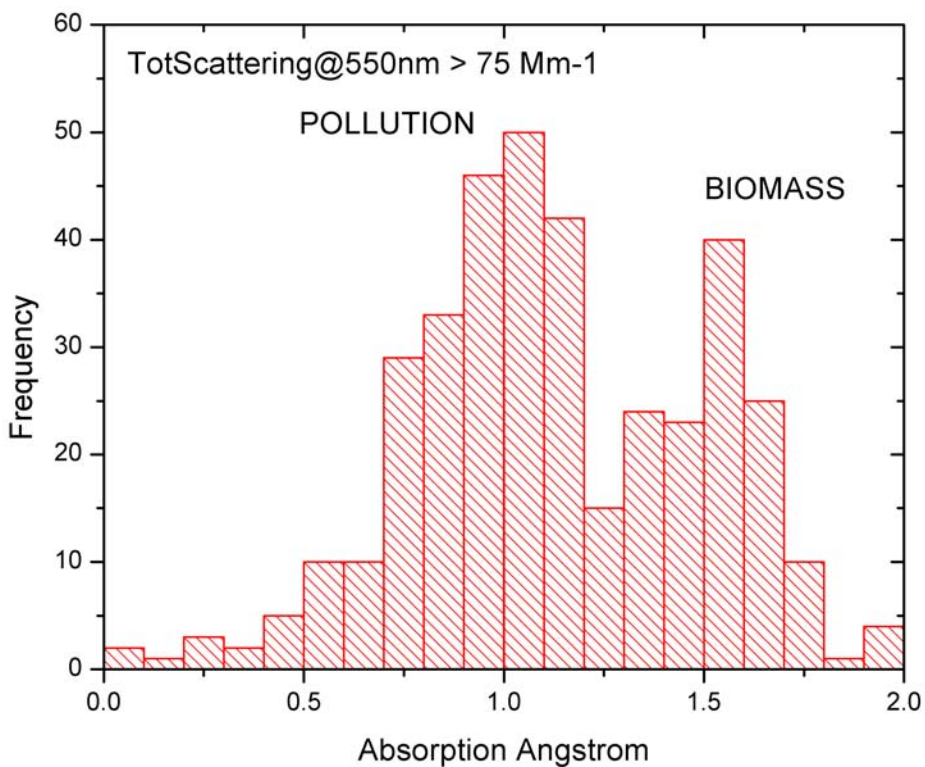


Biomass absorbs toward UV due to high temperature refractory organics

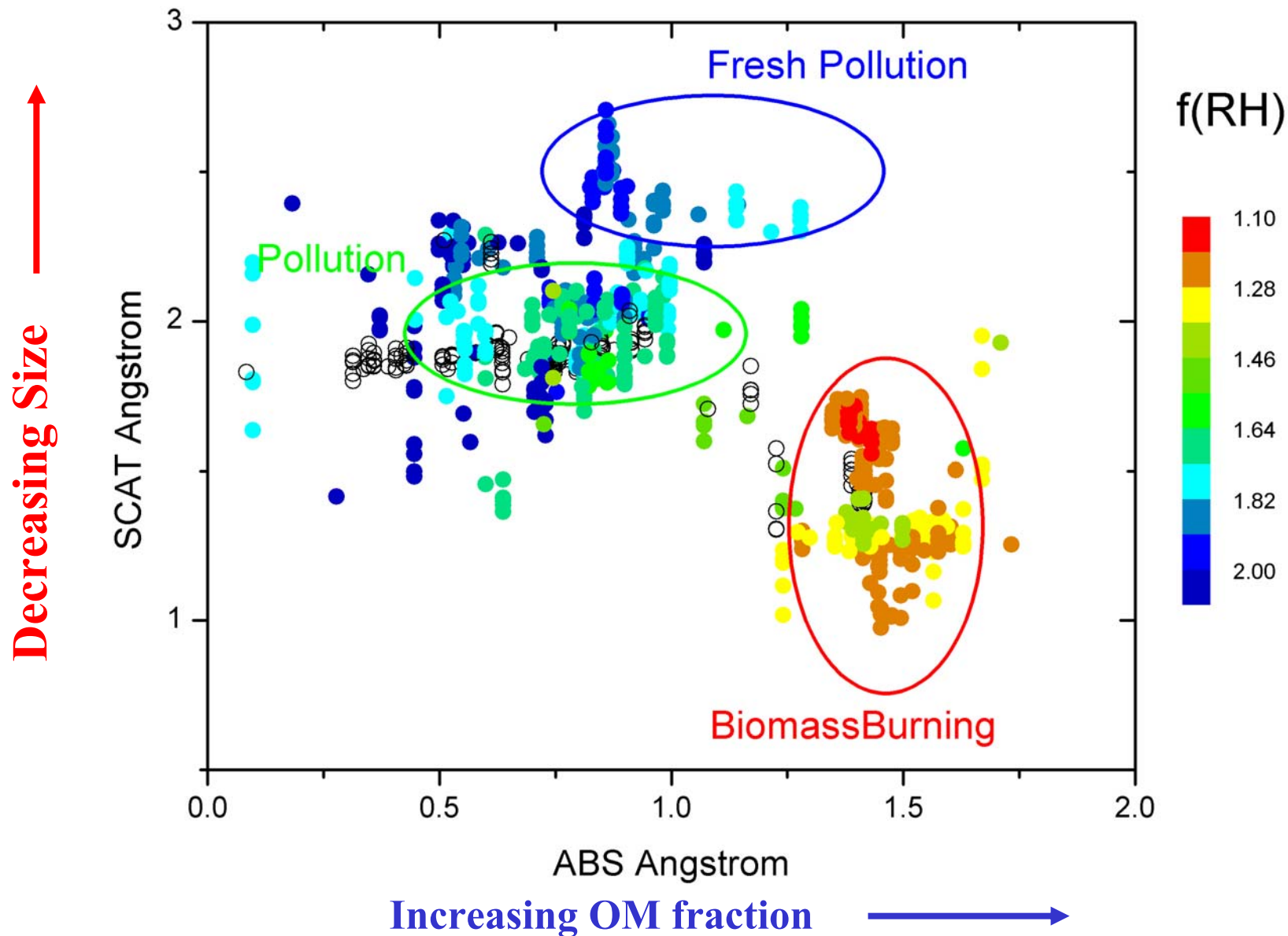
Spectral dependence of scattering and absorption also related to Differences in Size-Distributions of scattering and absorbing components



Histograms of distributions for Absorption Angstrom and Formaldehyde Pollution and Biomass Highlighted

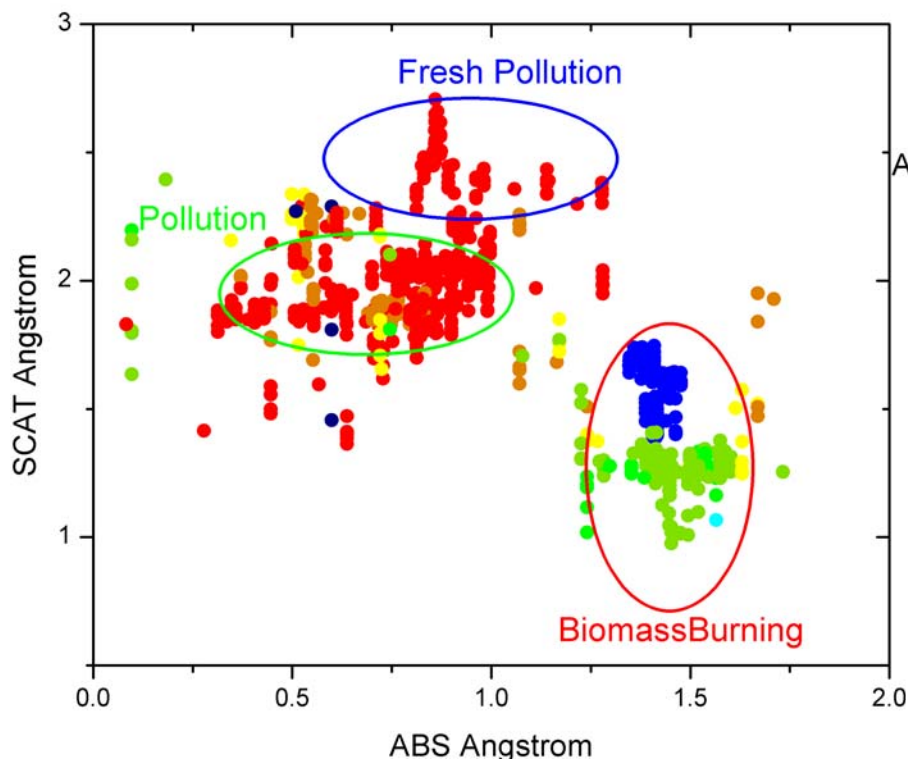


Source types resolved by spectral dependence of scattering and absorption
Color coded with $f(\text{RH})$

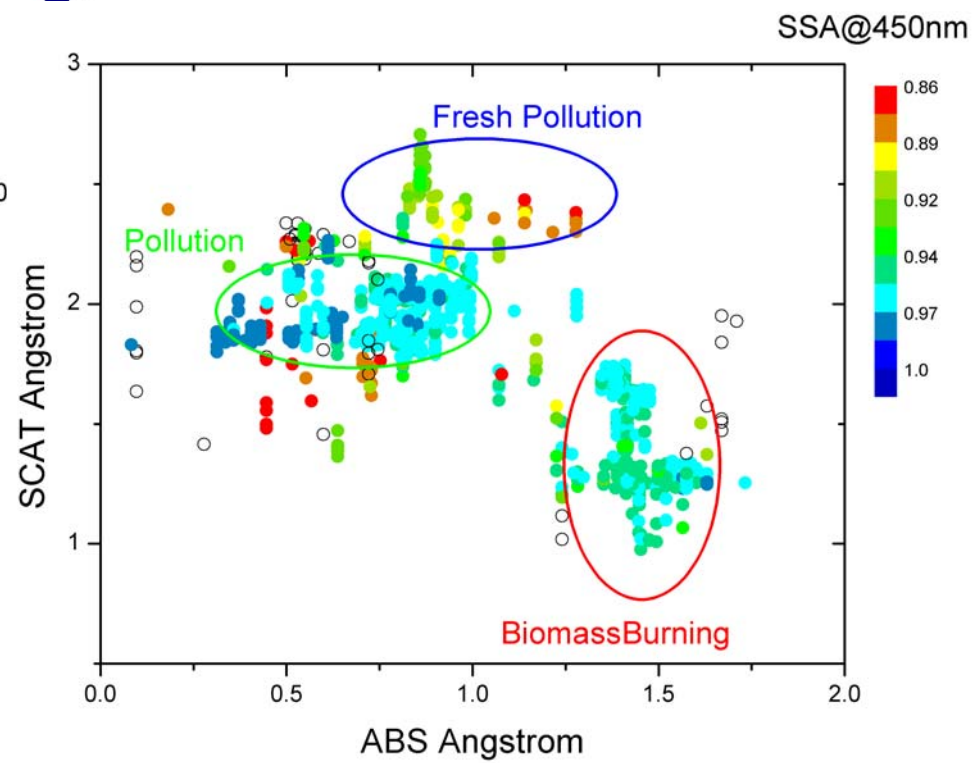


Source types resolved by spectral dependence of scattering and absorption

Altitude dependence and Relation to Single Scatter Albedo



Altitude, km

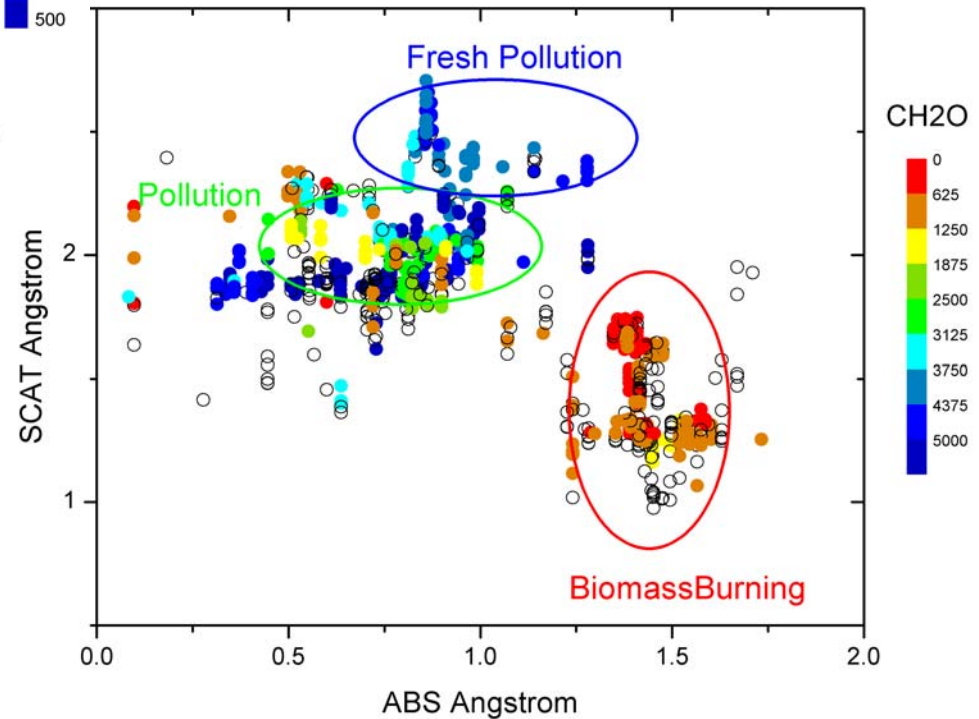
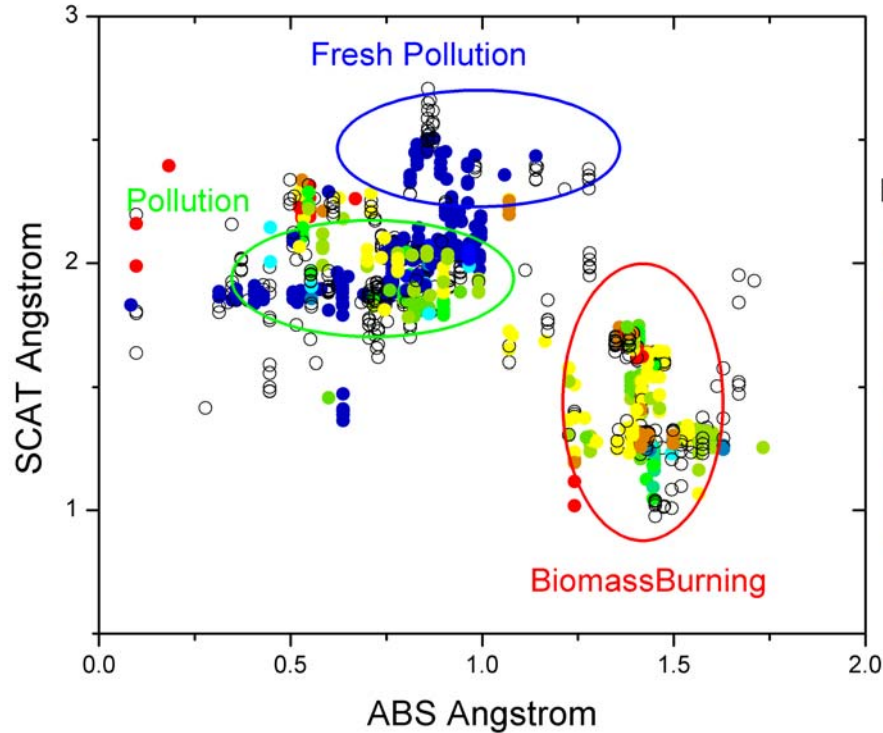


SSA@450nm



Source types resolved by spectral dependence of scattering and absorption

Relation to gas phase indicators



CONCLUSIONS

- Regional physio-chemical-optical characteristics may help stratify the roles of Black carbon and condensed species for model refinements.
- $f(RH)$ - Humidity growth is strongly modulated by OM fraction and must be recognized in optical properties reflected in models and satellite retrievals.
- Optical closure with satellites coupled to regional aerosol characterization shows promise in refining satellite retrievals and links to source emissions.
- Size, composition, optics and growth measurements provide a means to estimate the potential for satellite retrieval of CCN.

Potential INTEx Papers

- **Pollution and biomass burning aerosol over North America: Black carbon, $f(RH)$, microphysics and optics** – A. Clarke, V. Kapustin, S. Howell, Y. Shinozuka, C. McNaughton, R. Weber et al.
- **In situ aerosol optical closure experiments under MISR** – C. McNaughton, R. Kahn, P. Russell, Y. Shinozuka, A. Clarke et al.
- **An evaluation of multimodal aerosol retrievals for MODIS and MISR as a tool to obtain a CCN proxy** - Y. Shinozuka, V. Kapustin, A. Clarke, et al.
- **An assessment of measured & modeled aerosol size resolved concentrations and optical parameters during INTEx** – C. McNaughton, G. Carmichael, A. Clarke, Y. Tang, et al.)